TABLE 10.7 Method for Calculating Number of Occupants of a Building

Occupancy	Occupant/Seat or Floor Area/Occupant
Assembly, with fixed chairs	1 occupant/seat
with fixed seating benches	1 occupant/18 in.
with fixed seating booths	1 occupant/24 in.
with movable chairs	7 NFA[a]
with movable chairs and tables	15 NFA
with standing space only	3 NFA
Business area in a building	100 GFA[b]
Educational, classroom area	20 NFA
Shops and other vocational areas	50 NFA
Library reading rooms	50 NFA
Library stack areas	100 GFA
Institutional, inpatient areas	240 GFA
Outpatient area	100 GFA
Sleeping area	120 GFA
Mercantile, basement, and grade floor area	30 GFA
Area on other floors	60 GFA
Storage, stock, shipping areas	300 GFA
Parking garages	200 GFA
Residential	200 GFA
Miscellaneous (storage, mechanical equipment, etc.)	300 GFA

[a]NFA (net floor area) is defined as the actual occupied area of the space and shall not include unoccupied accessory areas or the thickness of walls.

[b]GFA (gross floor area) is defined as the floor area within the perimeter of the outside walls of the building under consideration.

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10.4.3 Planning Guidelines

Plumbing fixtures shall be installed so as to afford easy access for cleaning and maintenance. More space is required for the physically disabled. For example, a 42-in. clearance on one side of a WC stall is necessary to make room for a wheelchair.

Fig. 10.21 shows typical layouts of residential bathroom groups with piping in one or more walls. Toilets and washrooms should be located where they are easily accessible or likely to be expected: near building entries, waiting areas, elevator lobbies, stairways, telephone stations, etc.

Men's and women's toilets should be located in the same general area. They may be placed back to back or with some separation between them. When they are placed back to back, the cost of piping is substantially reduced for small and low-rise buildings. The cost of piping for large and high-rise buildings may not be significantly affected, since the large number of fixtures to be installed will probably require multiple stacks and risers in any case.

The designer must be careful to provide a visual barrier between the public passageway and the interior of the toilets when the door to the room is opened and there is a possibility that a reflected image may be seen through a mirror. Allow ample distance between fixtures and room surfaces. Refer to codes and standards for the minimum space requirements.

Fig. 10.22 shows several examples of public toilets and many of the design issues facing the architect.

10.5 SANITARY DRAINAGE SYSTEMS

Drainage in buildings consists of three major components: sanitary waste, storm water, and specialty waste, such as toxic, radioactive, chemical, or other processing wastes. Sanitary waste and storm water may be piped separately or combined, depending on the public sewer system to which the drainage is connected. Combined storm and sanitary

Example 10.12 If a 100,000-GFA office building has 80% of the GFA for office occupancy and 20% for miscellaneous spaces (storage and mechanical rooms), determine the number of building occupants and the minimum number of plumbing fixtures required.

Solution:

- According to Table 10.7, the number of building occupants shall be:

Business (office) Area:

80,000 ft^2/100	800 occupants
Miscellaneous spaces:	
20,000 ft^2/300	67 occupants
Total occupants	**867**
Assumed male occupants, 50% (use 60%)	520
Assumed female occupants, 50% (use 60%)	520

- From Table 10.6, the minimum required plumbing fixtures are as follows:

	WC	UR	LV	BT	DF	SK
Men	11	11	11	0	—	—
Women	22		11	0	—	—
For building	—		—	0	10	1/floor

sewer systems still exist in some major cities, carried over from the early practice of discharging untreated sewage into rivers. This practice is no longer permitted in the United States and most other developed, as well as developing, countries. Because of their pollutants, specialty wastes must be piped and treated separately.

Following are definitions of several terms commonly used in drainage systems:

- *Waste (liquid)* Liquid discharged from water-consuming equipment.
- *Sanitary waste* Liquid discharged from plumbing fixtures.
- *Soil (waste)* Liquid discharged from plumbing fixtures that contains or potentially contains fecal matter, such as liquid from a floor drain within a toilet.
- *Sanitary drain* Main drain of the sanitary drainage system within a building.
- *Sanitary sewer* Extension of the sanitary drain at the exterior of a building for connection to the public sewer or to a sewage disposal system.

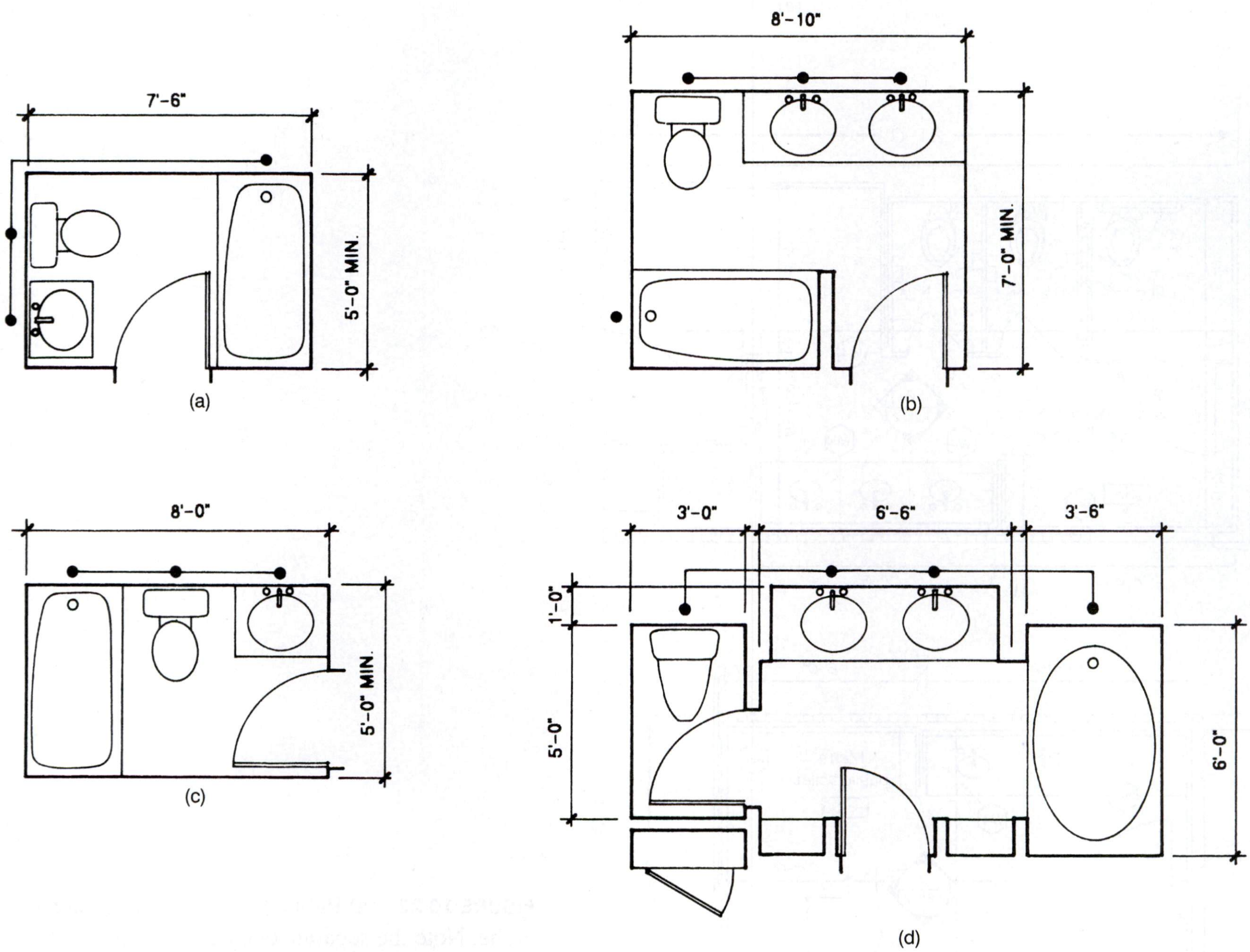
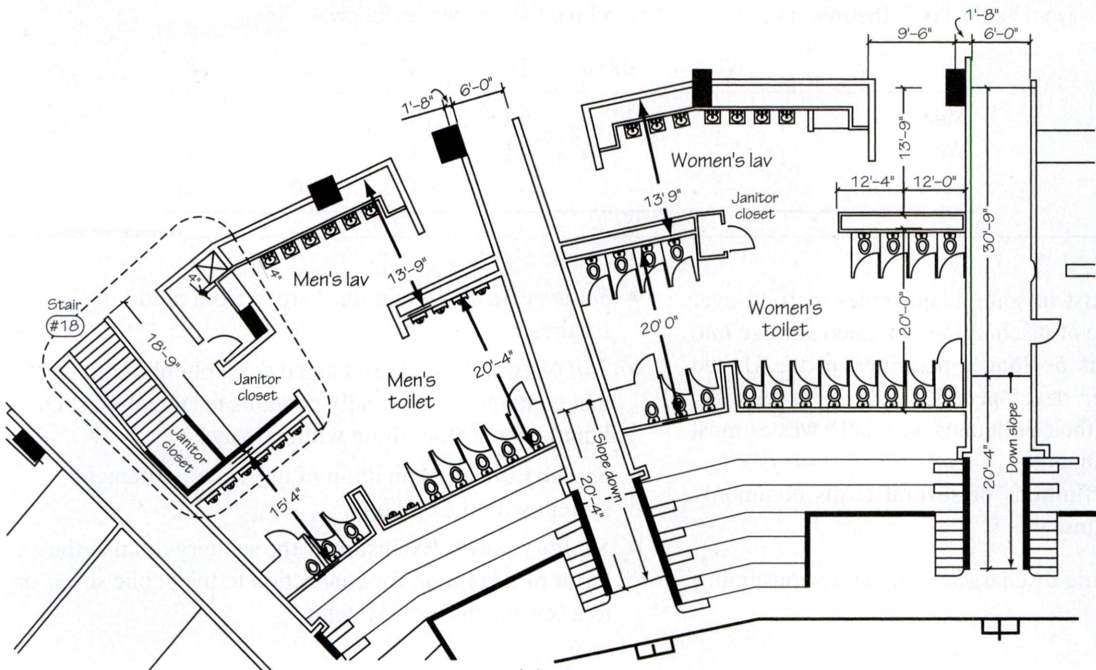


FIGURE 10.21. Typical residential bathroom plans.
(a) Basic three-fixture plan with piping on two walls.
(b) More spacious plan with piping on two walls.
(c) Basic three-fixture plan with piping on one wall (most economical).
(d) Deluxe plan including whirlpool and private water closet compartment.

(Courtesy: Tao and Lee Associates, Inc., Architects, St. Louis, MO)



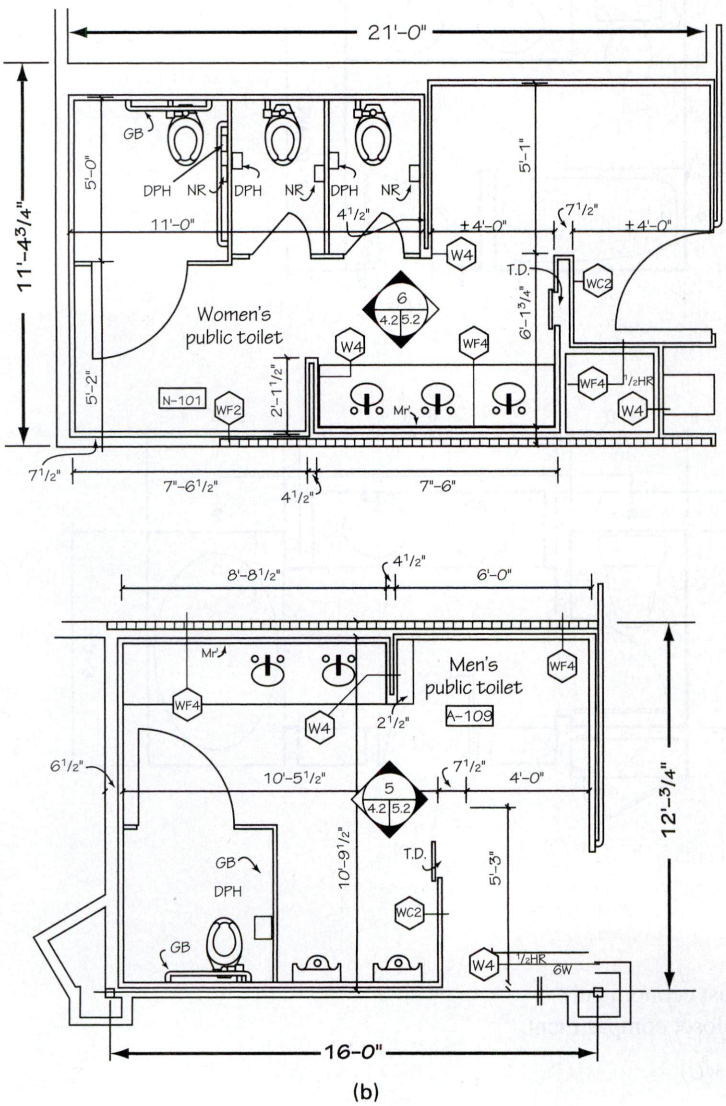


FIGURE 10.22. (a) Public toilets in a large sports arena. Note the separate entry and exit for each toilet, the toilets for the handicapped, and the janitors' closets. The men's and women's toilets are separated by a vomitory for noise control. (b) Typical public toilet layouts. Note the drinking fountain at the entry to the women's toilet, the screen walls for privacy, and the water closets for the handicapped.

- *Storm water* Rainwater collected from building roofs (roof drains) and from exterior areas (area drains). Depending on the purity of the water collected, rainwater may be classified as waste or may be stored for reuse, even as potable water.
- *Storm drain* Main drain of the storm water drainage system within a building.
- *Storm sewer* Sewer that is exterior to a building and that contains storm water only.
- *Combination sewer* Sewer that contains sanitary waste and storm water.

A sanitary drainage system is thus designed to carry away sanitary wastes (including soil wastes) from within a building to a public sewer or to a sewage disposal plant. The system may be designed to flow by gravity without mechanically or electrically powered equipment, or it may be designed to flow under pressure by pumping. The gravity system is, of course, more reliable and more economical to operate and thus should be used whenever feasible. The discussions in this section will deal with gravity flow only.

10.5.1 Drainage-Waste Venting

When the sanitary drainage system is connected to a public sewer, the entry of sewer gas, insects, or rodents through the system must be avoided. To overcome this problem, all drainage equipment (including all plumbing fixtures) connected to the sanitary drainage system must be separated by a liquid seal trap that acts to separate the building from the sewer. Each trap must be adequately vented to the atmosphere to prevent the liquid seal from being siphoned or sucked dry if a pressure differential is created between the building and the sewer owing to the flow of the drainage. Fig. 10.23 illustrates the operating principle of a liquid seal trap. Because of the importance of venting, a sanitary drainage system is often referred to as a *drainage-waste-venting* (DWV) system. Some of the important terms associated with a DWV system and their definitions are as follows:

- *Stack* Vertical portion of a DWV-piping system.
- *Waste stack* Vertical portion of a waste-piping system.
- *Soil stack* Vertical portion of a soil-piping system.

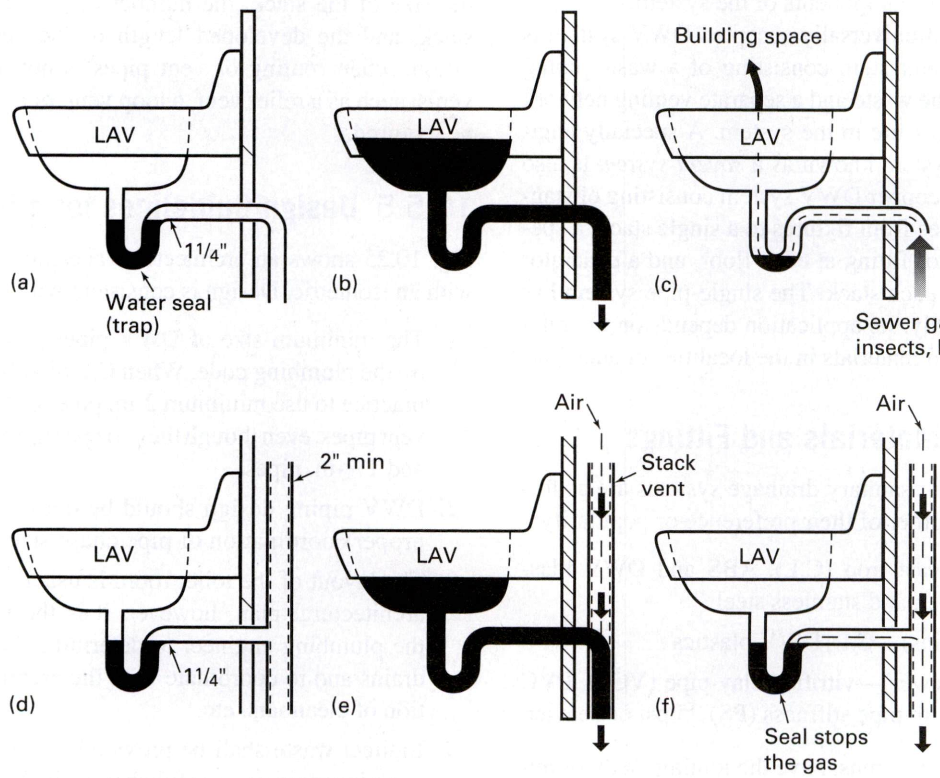


FIGURE 10.23. Liquid seal traps.

(a) With no vent, a trap may start out with a seal at no flow.
(b) During heavy drainage flow, the momentum of the flow can siphon out the liquid from the seal.
(c) As a result, the trap will be only partially filled and will allow sewer gas and other substances to enter the building.
(d) With proper venting, a trap is filled with liquid from the previous drainage flow.
(e) Even under heavy flow, air enters the vent pipe to break up the siphoning effect.
(f) As a result, the trap will continue to maintain a full depth of liquid.

- *Stack vent* Open-ended extension of a waste or soil stack above the highest horizontal drain connected to the stack.
- *Branch interval* Section of a soil or waste stack corresponding to one story in height (but in no case less than 8 ft).
- *Vent* Pipe open to the atmosphere.
- *Vent stack* Stack that does not carry waste of any kind and that is installed primarily for providing circulation of air to and from any part of the DWV system.
- *Branch vent* Branch of the venting system.
- *Common vent* Vent connected at the common connection of two fixtures.
- *Circuit vent* Branch vent that serves two or more traps and that extends from the downstream side of the highest fixture connection of a horizontal branch to the vent stack.
- *Crown vent* Vent connected to the crown of a trap.
- *Developed length* Total length of a pipe, measured along the centerline of the pipe.

Fig. 10.24 is an isometric diagram of a DWV system identifying the various components of the system.

The conventional universally accepted DWV system is essentially a two-pipe system consisting of a waste-piping network that drains the waste and a separate venting network to equalize the air pressure in the system. A specially engineered single-pipe system known as a *sovent system* is also available. It is an all-copper DWV system consisting of standard copper drainpipes from fixtures to a single stack, a specially designed aerator fitting at each floor, and a deaerator fitting at the base of each stack. The single-pipe system has been used satisfactorily. Its application depends on the relative costs of labor and materials in the localities in question.

10.5.2 Piping Materials and Fittings

The materials used for sanitary drainage systems are as follows, in the general order of their preference or popularity:

1. Aboveground—cast iron (C.I.), ABS and DWV plastics, DWV copper, and stainless steel
2. Underfloor (drains)—C.I., DWV plastics
3. Underground (sewer)—vitrified clay pipe (VCP), PVC sewer plastics with pipe stiffness (PS) 35 psi or heavier.

All pipes and fittings must have the joining methods appropriate for the material, such as the following:

1. Caulked joints, for hub-and-spigot types of C.I. pipes only
2. Threaded joints, for steel or heavy-wall plastic pipes
3. Soldered joints, for copper DWV pipes
4. Brazed joints, for heavy copper pipes only
5. Compression joints, for no-hub C.I., VCP, or plastic pipes
6. Gasket joints, for hub-and-spigot C.I. pipes
7. Flexible compression joints, for VCP pipes
8. Solvent joints, for plastic pipes
9. Transition joints, specially made for joining different materials

10.5.3 Sizing of Drain Lines

The capacity of (waste or soil) drainpipes of the DWV system depends on two major factors: the slope of the pipes and the dfu they serve. All horizontal drain lines should have a uniform downward slope in the direction of flow. If the slope is not steep enough, solid contents in the liquid may drop out. If the slope is too steep, turbulence flow and erosion of the pipes may occur. In general, the slope shall not be less than $^1/_4$ in. per foot (approximately a 2 percent slope) for 3-in.-diameter and smaller horizontal lines and $^1/_8$ in. per foot (approximately a 1 percent slope) for 4-in.-diameter and larger horizontal lines

10.5.4 Sizing of Vent Pipes

The capacity of vent pipes depends on three major factors: the size of the stack, the number of dfu connected on the stack, and the developed length of the vent pipe. In addition, when routing of vent pipes is not direct, auxiliary vents, such as a relief vent, a loop vent, or a crown vent, will be required.

10.5.5 Design Guidelines for a DWV System

Fig. 10.25 shows an architectural and plumbing plan along with an isometric. Design is consistent with these guidelines:

1. The minimum size of DWV pipes is governed strictly by the plumbing code. When C.I. pipe is used, it is good practice to use minimum 2-in. pipe for branch drain and vent pipes, even though the code permits the use of $1^1/_4$-in. and $1^1/_2$-in. pipes.
2. DWV piping design should be optimized through the proper coordination of pipe chase sizes and locations.
3. The layout of the toilet room is usually initiated by the architectural plan; however, it is the responsibility of the plumbing engineer to determine the need for floor drains and to coordinate with the architect on the location of cleanouts, etc.
4. Indirect waste shall be provided for all equipment that contains toxic or harmful chemicals. The drainage shall be piped to a separate receptor for sedimentation, neutralization, or filtration before being discharged into the public sewer system.
5. Other than intermittent discharges into the drainage system from dishwashing and laundry equipment with water at a temperature of 140°F or above, no high-temperature waste or steam pipe shall discharge into the drainage system without subcooling the effluent prior to connecting to the sanitary sewer.

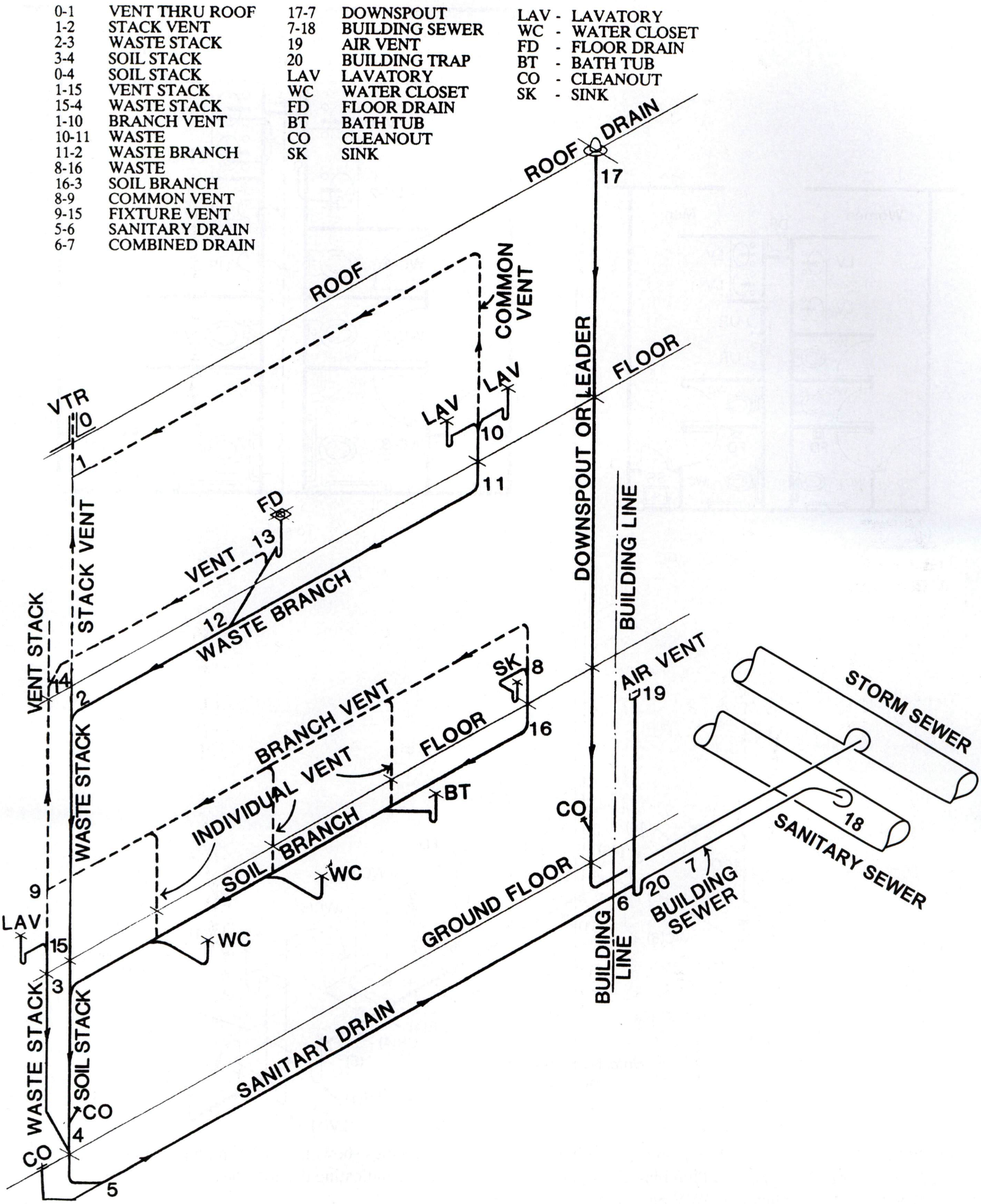


FIGURE 10.24. Isometric diagram of a DWV drainage system identifying the various components of the system. *(Note: When the public sewer is a combined sanitary and storm sewer, building sewers may also be combined at the site line.)*

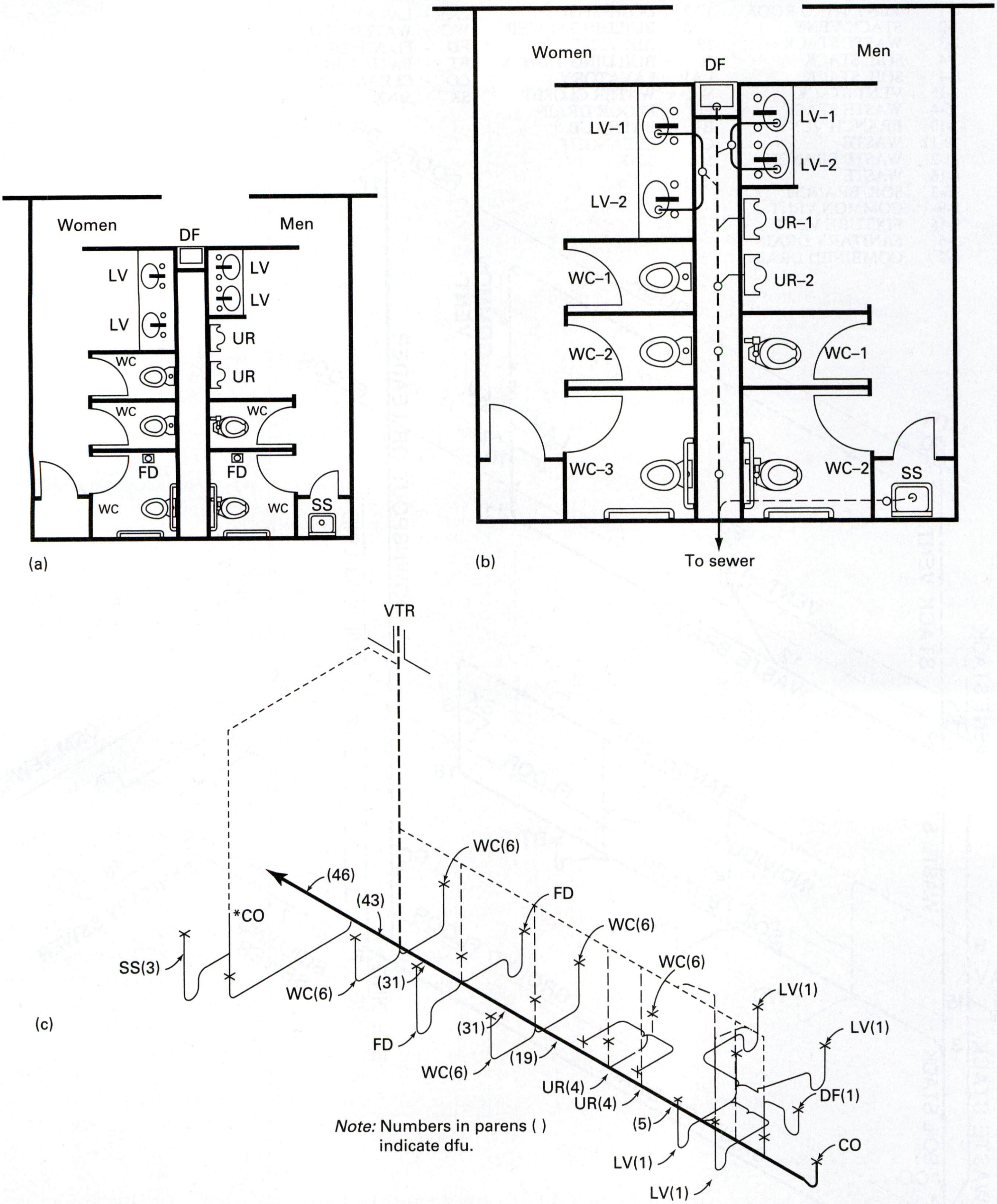


FIGURE 10.25. Architectural floor plan of two toilets and plumbing drawings showing a DWV-piping system. (a) Architectural floor plan. (b) Plumbing floor plan. (c) DWV isometric indicating dfu load on waste branches. (d) DWV isometric indicating DWV pipe sizes.

(Note: 2-in. minimum vent pipe is used for C.I. pipes.)

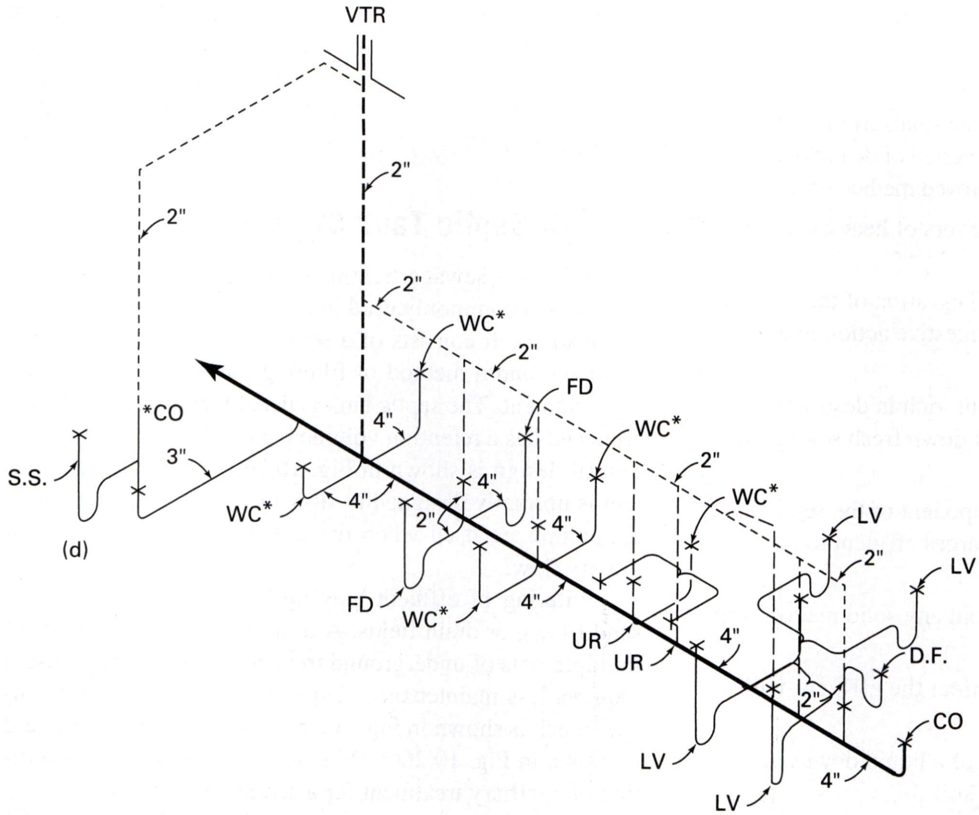


FIGURE 10.25. *(Continued)*

6. All plumbing fixtures or drainage equipment without a built-in trap must be connected through an external trap.
7. All traps must be vented.
8. All horizontal drainage piping shall be installed in alignment at a uniform slope not less than $\frac{1}{4}$ in. per foot for a diameter of 3 in. and less, and not less than $\frac{1}{8}$ in. per foot for a diameter of 4 in. or more. In rare cases, $\frac{1}{16}$ in. per foot is permitted by agreement with the code-enforcing authority. A slope greater than 1 in. per foot should be avoided when the waste contains solid matter.
9. Cleanouts shall be installed at the base of drainage stacks and at the beginning of main horizontal branches so that the entire DWV system can be cleaned and cleared to prevent clogging.
10. Grease-laden waste from kitchens should be piped directly to the building drain or stack whenever practical. A grease trap shall be installed for commercial kitchens, prior to connection to the waste pipe.
11. Waste containing high volumes of insoluble matter, such as sand or plaster shall be intercepted by sediment basins or catch basins prior to discharging into the sewer.
12. Waste containing oil, such as drains from a commercial garage, shall be connected through an oil interceptor.
13. A 4-in. waste (soil) horizontal branch shall be used for a WC outlet even though plumbing codes do allow the use of a 3-in. branch for a tank type of WC in public buildings and up to two bathroom groups in private residences. Experience indicates that the increased horizontal branch will substantially reduce the chance of blockage.

10.6 SEWAGE TREATMENT AND DISPOSAL

To protect water resources and the greater environment, all waste from buildings and industrial processes must be treated to meet certain standards of quality. Domestic sewage from dwellings and DWV systems in buildings are permitted to be discharged into the public sewer system, which provides the necessary treatment prior to its discharge into nature. When public sewers are not accessible, or when there is no public sewer system in the vicinity of a building or buildings, a private sewage treatment system will have to be constructed.

Following are the definitions of some commonly used terms related to the subject of sewage treatment methods and disposal processes:

- *Digestion* That portion of the sewage treatment process in which biochemical decomposition of organic matter takes place, resulting in the formation of simple organic and mineral substances. Also known as *aerobic (bacterial) digestion.*
- *Influent* Untreated sewage flowing into a treatment system.